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Distribution of Multimedia Objects

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During the past decades, distributed computing system has provided various advantages of enhanced performance, reliability, availability, resource sharing, and modularity to an organization. The emergence of high speed network with powerful workstations has accelerated the development of distributed computing system. On the other hand, the need for the direct manipulation of various forms of information, such as video, audio, and image, and the ability to integrate these forms of information has led to the development of distributed multimedia systems (Bufford, 1994; Williams and Blair, 1994). These systems are generally implemented using the Object Oriented Technology (Blair, Dark, and Davies, 1994).

Development of distributed multimedia systems poses many challenges such as: need for faster networks, high performance processing, and proper storage systems. Additionally, the design of these systems requires consideration of issues such as: the synchronization of various objects, the presentation architecture, the design of the communication network, and the distribution of hardware and objects. This study focuses on the distribution of multimedia objects.

Most past research related to data distribution focuses on textual data types and relational databases (Dowdy and Foster, 1982; Dutta, Koehler, and Whinston, 1982; Hevner and Rao, 1988; Houstis, 1990; Jain, 1987; Wah and Lien, 1985). The results of these research cannot be directly used for distribution of multimedia objects. Thus, different approaches and models are required to manage multimedia objects in a distributed system. Some researchers have suggested the possible strategies for the object distribution (Blair and Lea, 1992; Purao, Jain, and Nazareth, 1995). Purao et al.(1995) proposes the object allocation strategy over distributed heterogeneous architectures to minimize communication and storage cost. However, the multimedia object allocation problem has not been addressed. Little and Venkatesh (1994) investigate the assignment problem of video object in terms of popularity and daily load peaks. This paper proposes a strategy for the distribution of multimedia objects.

Multimedia data have different characteristics which distinguishes it from conventional data.

1. *Large data size* : Multimedia data require large storage space and transfer bandwidth. For example, a 2-hour movie might require over 1 Gbyte of storage.

2. *Real-time retrieval requirement* : Multimedia data are sensitive to timing during delivery. Multimedia data usually require synchronizing two or more data types as the object plays out.

3. *Multiple data streams* : A multimedia object may consist of text, audio, video, and image data. Each data type requires very different storage space and retrieval rate.

A typical data transfer rate required for uncompressed multimedia data is shown in table 1 (Gemmell, Vin, Kandlur, Rangan, and Rowe, 1995).

Table 1. Typical data transfer rate required for uncompressed multimedia data

Media Type	Specifications	Data rate (per second)
CD-quality	2 channel	1.4 Mbits

audio	16-bit samples at 44.1 kHz	
MPEG-2-encoded video	640 x 480 pixels/frame, 24 bits/pixel	0.42 Mbytes
NTSC-quality video	640 x 480 pixels/frame, 24 bits/pixel	27 Mbytes

Based upon the above characteristics, we consider the usage and update frequency as an important factor in making allocation decisions. The design objectives are: minimize storage cost and minimize transmission cost. Several constraints are considered such as: replication, bandwidth, hardware capability and synchronization requirements.

The formulation of a decision model for the distribution of multimedia objects has been presented here.

The following notations are used for the decision model:

S Set of all network sites : i, j S

O Set of multimedia objects : o O

M Type of multimedia data :

Ma (audio), Mv (video), Mt (text), Mi (image) Ma, Mi, Mt, Mv M

C Storage cost per unit

T Transmission cost per unit

L_o Storage required by object *o* (k bytes)

F_{oi} Access frequency of object *o* from site *i*

U_{oi} Update frequency of object *o* from site *i*

D_{ij} Distance between site *i* and *j*

P_{om} Type of multimedia objects

1 if object *o* is of data type *m*

0 otherwise

X_{oi} Object *o* is allocated to site *i*

1 if object *o* is available at site *i*

0 otherwise

Y_{oij} Object *o* required at site *i* is accessed from site *j*

1 if object *o* required at site *i* is

accessed from site *j*

0 otherwise

B_{mij} Bandwidth between site *i* and *j* is sufficient to transmit data type *m*

1 if bandwidth is sufficient

0 otherwise

H_{mi} Site *i* is capable of handling data type *m*

1 if site i is capable

0 otherwise

The objective function is,

Minimize Total Cost

Total Cost = Storage Cost + Communication Cost

Total Cost = $C * L_o * X_{oi}$ +

iS oO

$T * [\ F_{oi} * L_o * (1 - X_{oi}) * (Y_{oij} * X_{oj}\ )$

iS jS oO

$+\ U_{oi} * L_o * (X_{oi} + X_{oj})\ ]$

iS jS oO

The constraints are,

1) at least one copy of object should be allocated :

X_{oi} 1 for o O

iS

2) site should be capable of handling the object type:

H_{mi} X_{oi} * P_{om}

for i S, o O, m M

3) bandwidth is sufficient for accessing the object type stored at site *j* from site *i* :

B_{mij} (1 - X_{oi}) * (Y_{oij} * X_{oj}) * P_{om}

for i, j S, o O, m M

4) bandwidth is sufficient for updating the object type stored at site *j* from site *i* :

B_{mij} X_{oi} * P_{om}

B_{mij} X_{oj} * P_{om}

for i, j S, o O, m M

5) object *o* required at site *i* is accessed from site *j* :

Y_{oij} = [(1 - X_{oi}) * minimum (D_{ij} * X_{oj})] / D_{ij}

for i, j S, o O, m M

A heuristic technique is used to solve the model. The model is tested on an example problem.

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[A longer version of the paper is available.]